2019

Forest Health Annual Report

DEPARTMENT OF NATURAL RESOURCES

The Minnesota Department of Natural Resources Forest Health Highlights report was created by the Division of Forestry forest health unit.

Cover photo: Oak with symptoms of twolined chestnut borer.

Photo credits: photos and other images are from DNR staff unless indicated otherwise.

Projects were funded in whole or in part through a grant awarded by the USDA Forest Service, Northeastern area State and Private Forestry.

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Summary of 2019 Forest Health Annual Report

Each year, the Minnesota DNR forest health staff put together an annual report to provide information about significant forest insect and disease damage recorded in our aerial survey and to highlight staff accomplishments throughout the year. The report is of special interest to DNR Division of Forestry staff and other foresters who can use the report to prepare for pest outbreaks, for example, and for anyone who is interested in knowing what is causing damage to the forest canopy. The statewide survey includes roughly 13 million acres of forested land.

Forest health specialists interpret data collected in aerial and ground surveys for forest managers. They respond to requests for information or assistance from forest managers and forestland owners on state, county, municipal, and private lands. Staff priority is to investigate serious insect and disease threats to state lands.

Forest health staff also provide expertise in DNR policy development regarding forest health. They provide training not only for DNR employees but for other agencies and organizations. Staff create outreach products that reach a wide audience, including web pages and newsletters.

Highlights of this year's survey:

- Eastern larch beetle – 19th year of continuous outbreak and highest amount of affected acres; nearly 50 percent of tamarack in the state affected.
- Spruce budworm – localized outbreak continues in the Arrowhead Region, with the highest total of affected acres in 13 years.
- Forest tent caterpillar – barely noticeable, but may begin to see an increase in the next few years if there was a true population peak in 2013.

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New forest health program staff

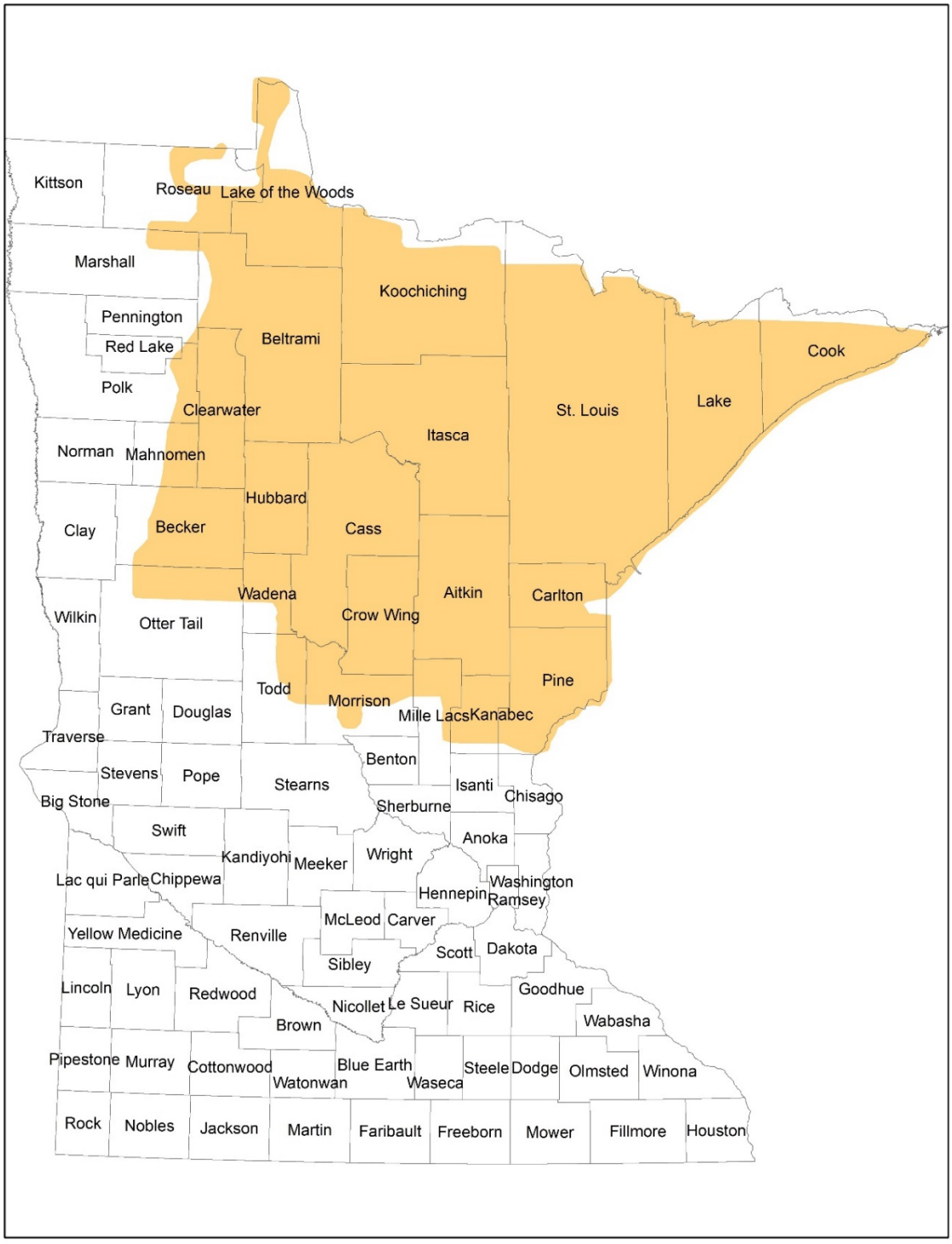
In 2018, we reported that we had filled our program's three vacant positions, bringing us from one to four forest health specialists. We are very happy to introduce our new regional specialists.

Megan O'Neil is one of two forest health specialist in the northwest region. She is from southern Michigan and has bachelor's and master's degrees from Michigan Technological University. Megan became fascinated with forest health issues as the impact of emerald ash borer became evident in the greater Detroit area. She gained experience in forest health while working in a lab at Michigan Tech, monitoring emerald ash borer and other forest health pests such as hemlock woolly adelgid across the Upper and Lower Peninsulas of Michigan.

Rachael Nicoll (rhymes with pickle) is also a forest health specialist in the northwest region, but is stationed in Brainerd. Rachael is a native Minnesotan from the central part of the state, and says that growing up in the woods fostered her passion for the outdoors as well as a desire to devote her career to making progress on the complex challenges of natural resources management. Rachael has bachelor's and master's degrees from the University of Minnesota. She studied the dispersal capacity of larval gypsy moth and analyzed perceptions of the gypsy moth invasion in Minnesota.

Eric Otto is the forest health specialist in the northeast region. He is also native to Minnesota, and similar to Rachael, embarked on a natural resources career through a love of exploring the woods outside his childhood home. Eric has a bachelor's degree from the University of Minnesota, and became interested in forest health while working in a forest pathology lab as an undergraduate. Eric is currently finishing his PhD dissertation on Heterobasidion root disease.

Aerial Survey Coverage in 2019



The 2019 aerial survey covered most of northern Minnesota.

Annual aerial survey of forest canopy

Since the early 1950s, the Minnesota Department of Natural Resources (DNR) aerial survey has been a valuable tool for monitoring forest canopy health across 13 million acres of forest land (all ownerships: federal, state, county, tribal, and private). The main problems consistently recorded with surveys are large insect outbreaks, wind events, and fire damage. Other recorded problems, such as forest damage from floods or tree-boring insects, do not always coincide with survey timing, or occur in areas that typically are not surveyed (e.g., in southwest Minnesota along the Minnesota River), so their impact is often underestimated. Finally, problems such as root diseases, wilts, and black ash decline cannot be consistently detected from the air and are therefore not recorded in surveys.

Annual surveys are accomplished through the collaboration of the DNR forest health and resource assessment units and the USDA Forest Service Region 9, St. Paul Field Office, State and Private Forestry (USFS). Survey results can be found in the Minnesota Geospatial Commons (keywords “forest health”). The summary table below shows the amount of acres damaged by insects, disease, and other factors as seen in aerial surveys.

Comparison of aerial survey results from 2017 to 2019

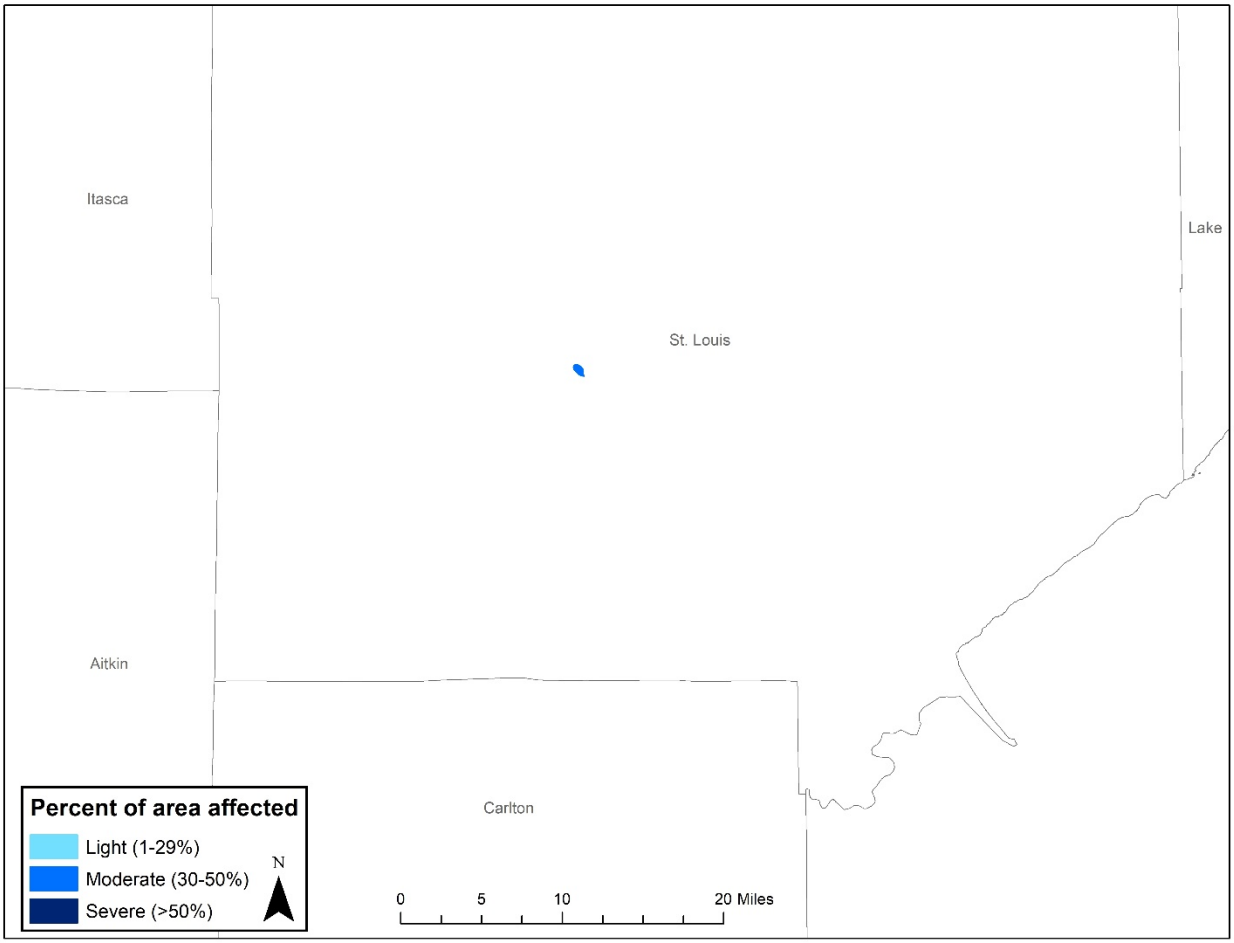
Damage agent	Acres affected in 2017	Acres affected in 2018	Acres affected in 2019	Comments
Arborvitae leafminer	11,752	3,977	165	The 2018 figure is an underestimate: see larch casebearer.
Aspen and birch decline	19,054	18,378	16,905	
Bark beetles on pine, spruce, and fir	1,803	375	2,778	
Eastern larch beetle	211,131	180,825	244,302	2019 was the 19th straight year of a continuous outbreak and had the highest amount of affected acres.
Emerald ash borer	Not surveyed	1,881	Not surveyed	Only affected forests in southeast Minnesota were surveyed in 2018.
Flooding	6,427	5,121	9,073	The 2019 figure is an underestimate.
Forest tent caterpillar	40,433	28,078	1,295	
Hail	3,479	0	0	
Jack pine budworm	4,275	193	609	
Larch casebearer	21,938	15,817	7,168	The 2018 figure was an underestimate: we were unable to separate damage from arborvitae leafminer and larch casebearer on 13,684 acres.
Northern hardwood decline	15	0	0	
Spruce budworm	68,213	196,460	201,711	2019 had the highest total of affected acres in 13 years.
Twolined chestnut borer	2,845	1,011	220	
Wildfire	333	554	275	
Wind damage	6,037	3,630	5,255	

Arborvitae leafminer

Arborvitae leafminer was first noticed in Minnesota during the 2017 aerial survey. With help from the University of Minnesota Plant Disease Clinic and MN DNR foresters we were able to positively identify arborvitae leafminer as the cause of damage to thousands of acres of northern white cedar in 2018. Arborvitae leafminer is a native insect that feeds inside the needles of white cedar and leaves an extremely small exit hole when it emerges. Due to difficult access in white cedar swamps, ground-truthing for the presence of this insect can be difficult.

This year we mapped only a small area of 165 acres of leafminer damage to northern white cedar, a significant drop from last year. The damage was recorded in St. Louis County southeast of Meadowlands. The total acreage affected by arborvitae leafminer in 2019 is likely an underestimate.

Tiny exit hole made by arborvitae leaf miner on northern white cedar.

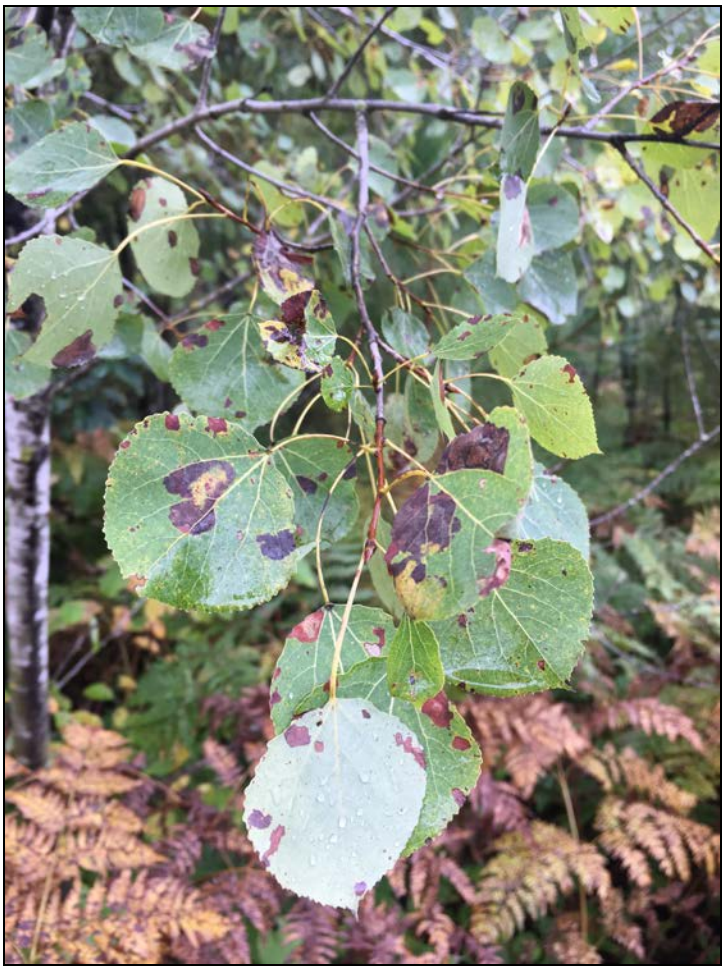


Leafminer damage to northern white cedar was located in St. Louis County.

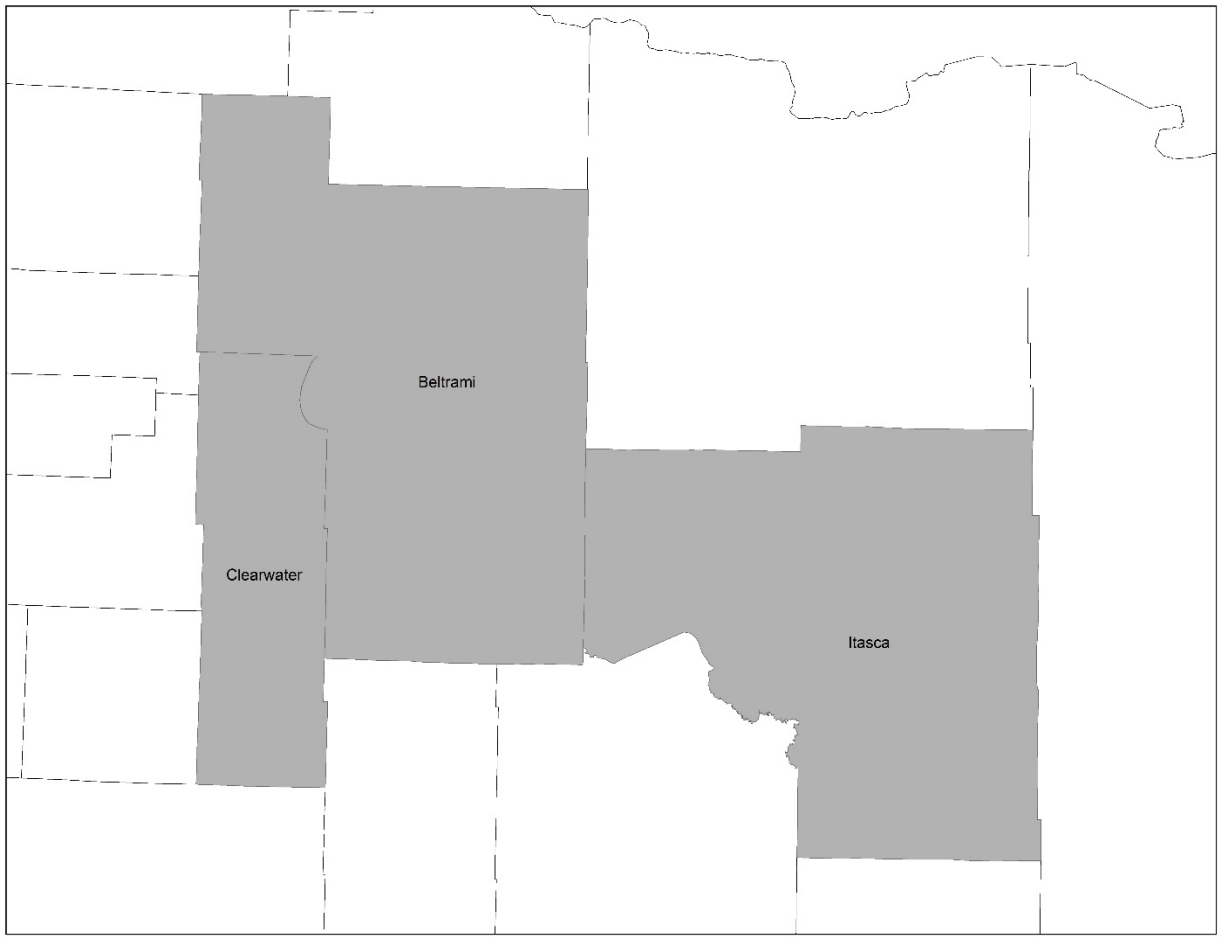
Aspen blotchminer

Aspen blotchminer can cause crowns of aspen trees to thin. Damaged leaves initially are off-color with yellow blotches, but by early September the blotches become brown. Infested leaves may eventually curl. The blotches can be numerous and concerning, but aspen trees can tolerate the damage. Overall, the impact on the health of aspen trees is minimal.

We observed aspen blotchminer damage frequently from July to October on trembling aspen. Due to staff short-term staff vacancies in 2018, we were unable to determine if there was more damage from blotchminer on aspen in 2019 than in 2018. We suspect the trend of aspen blotchminer damage increased in 2019 from the prior year. It was not reported as a problem in 2017.



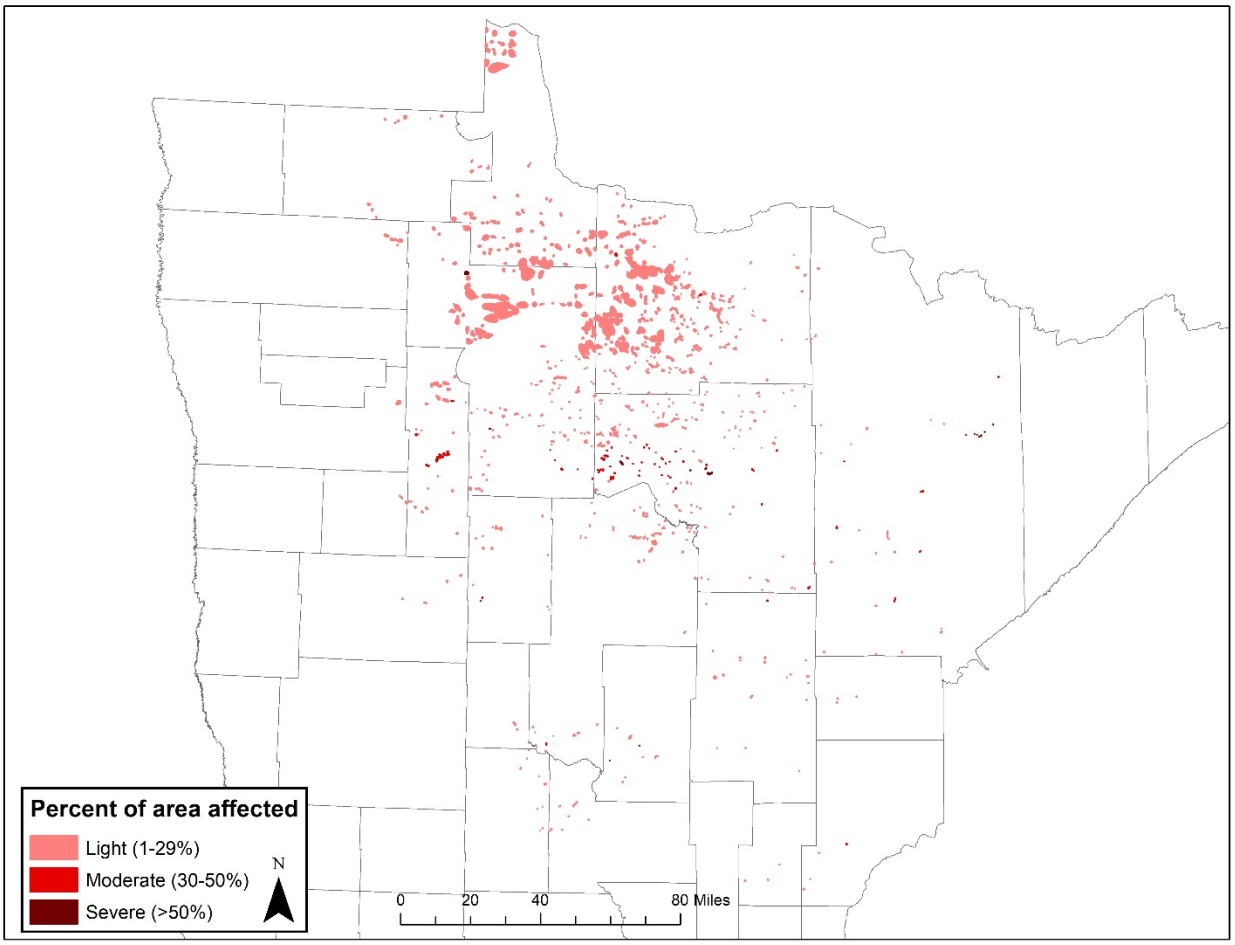
Aspen blotchminer damage on aspen.



Blotchminer damage occurred in Beltrami, Clearwater, and Itasca counties.

Eastern larch beetle

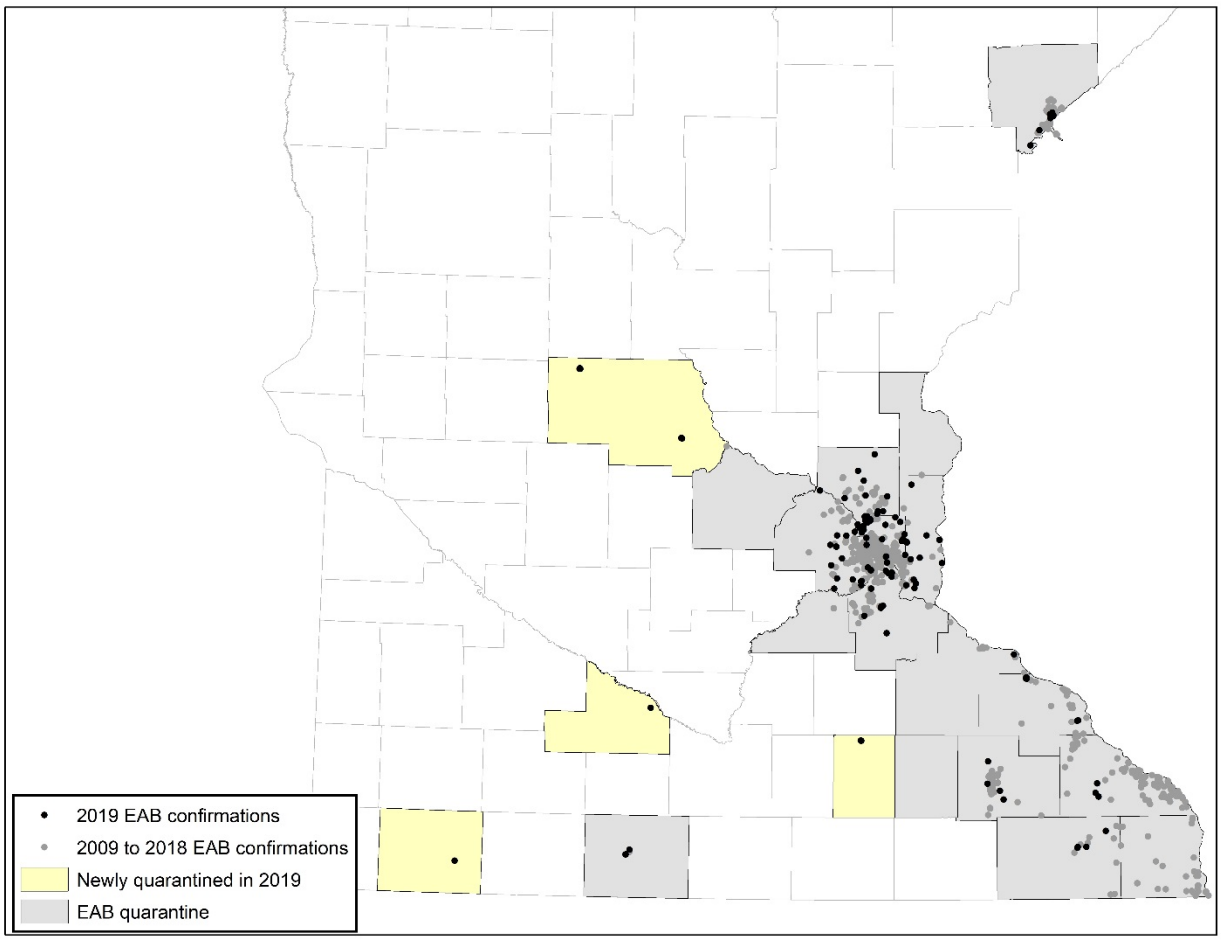
Eastern larch beetle is native to Minnesota and is known to usually attack weakened tamarack. Since 2001, beetle populations have been at record levels and have caused mortality of healthy tamaracks larger than four inches in diameter. The DNR forest health team has been monitoring the outbreak since it began in 2001 and has been tracking damaged tamarack as tree conditions decline in the northern portion of the state. We found 244,302 acres affected to some degree by eastern larch beetle in 2019; there has been an upward trend of damaged acres since the beginning of the outbreak. Since then, about 666,000 acres, or almost 50 percent of tamarack in the state, have been impacted to some degree by eastern larch beetle.



Eastern larch beetle damage in northern Minnesota.

Emerald ash borer

The Minnesota Department of Agriculture (MDA) is the lead agency for the emerald ash borer program in the state. Emerald ash borer was found for the first time in 2019 in Brown, Nobles, Stearns, and Steele counties.



Emerald ash borer confirmations and quarantines.

Biological control

In 2019, MDA staff released 47,616 parasitoids, including *Oobius agrili*, *Tetrastichus planipennisi*, and *Spathius galinae*. Each site averaged around 6,000 released parasitoids. Release sites were in eight locations where emerald ash borer has been detected; distribution as follows: one site in each of Anoka, Hennepin, Goodhue, Olmsted, and Wabasha counties, two sites in Dakota County, and one site in Duluth (St. Louis County). The MDA continues to confirm parasitoid survival and reproduction using bark, whole-tree, and yellow pan trap sampling methods.

Winter mortality

The MDA assessed winter impacts on emerald ash borer during sampling in spring, 2019 at Fort Snelling State Park in the metro Twin Cities, Sauk Centre, and Duluth. Many larvae were visibly discolored and dead at the point of sampling.

- 82-99 percent mortality at Sauk Centre; air temperature below -30° F
- 67-89 percent mortality in Duluth; air temperature below -30° F
- 40-86 percent mortality at Fort Snelling; air temperature below -20° F

While there was definitely some emerald ash borer mortality, certainly many survived the cold, and populations of emerald ash borer will continue to exist in Minnesota.

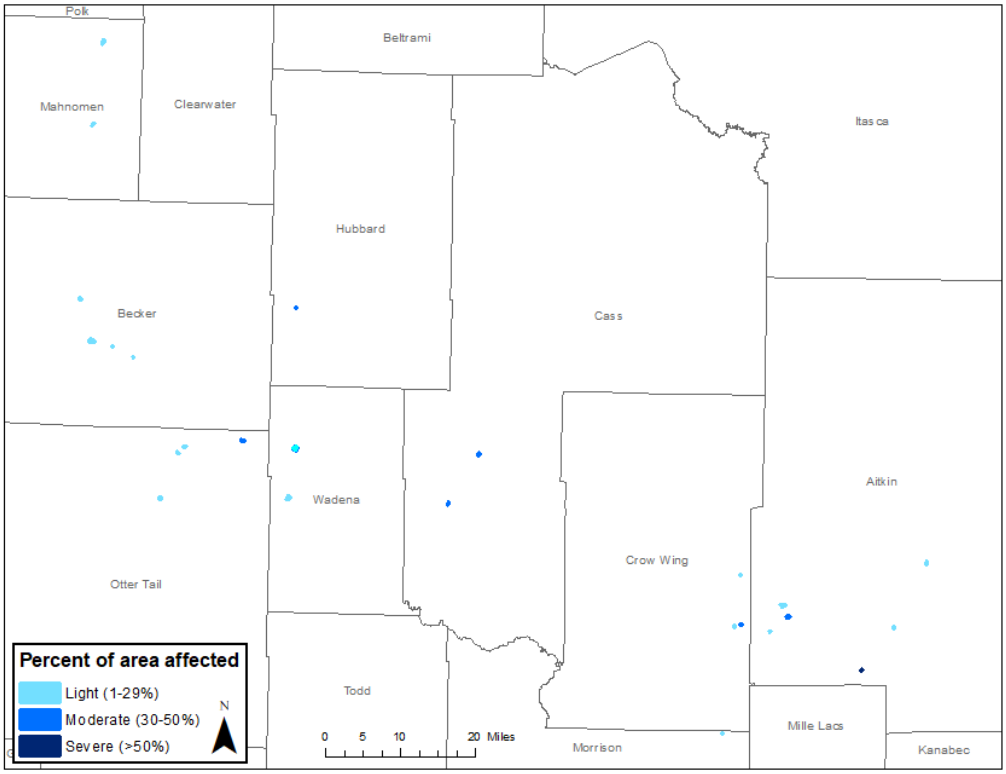
Dead emerald ash borer larva. Photo by Rob Venette, USDA Forest Service

Forest tent caterpillar

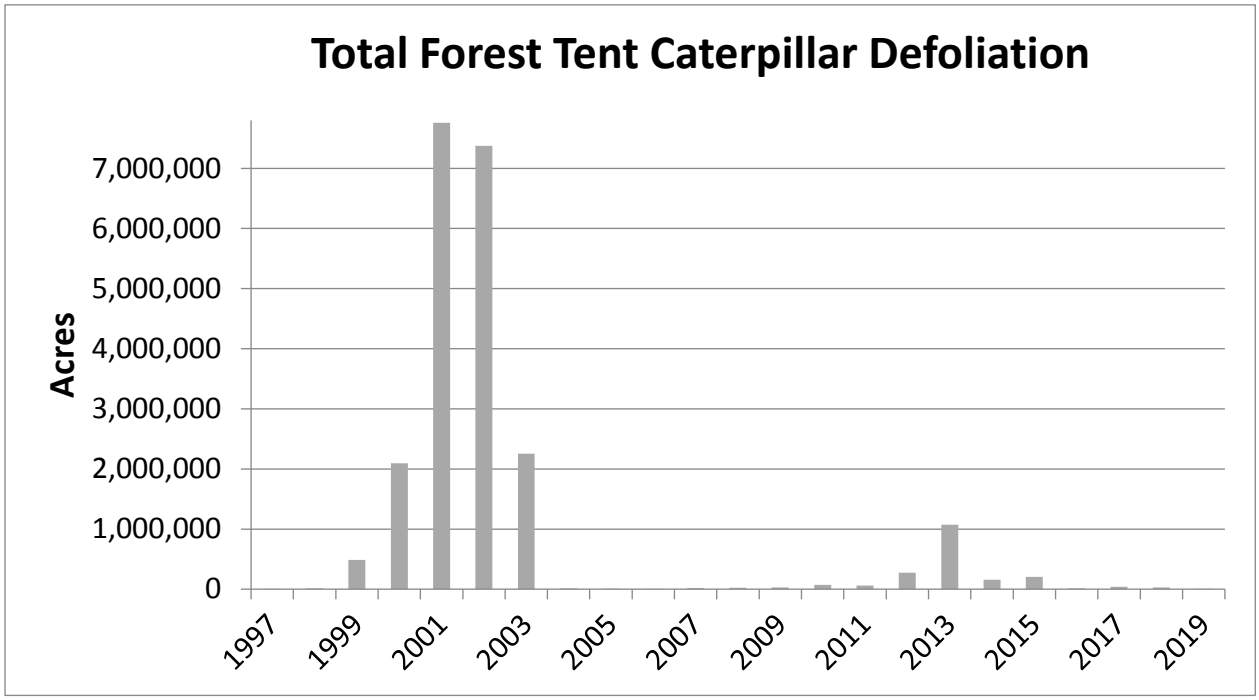
Forest tent caterpillar is a native insect that feeds primarily on aspen, oak, birch, and basswood. We mapped 1,295 acres of forest tent caterpillar defoliation and mortality in 2019, a decrease of more than 96 percent from 2018. There were only 179 acres with severe defoliation. There has been a general decline in acres impacted by forest tent caterpillar since 2012. That trend continued in 2019.

Forest tent caterpillar impacts have been relatively low since the early 2000s. The reason for this recent trend is unknown. However, changes in aerial survey protocols and technology as well as inherent challenges in aerial detection (e.g., weather conditions) limit our ability to assess recent population dynamics. Aerial surveys conducted from 2004 to 2016 recorded trace, or very light, defoliation that likely had negligible impacts to tree health. The second figure below includes these trace levels of defoliation through 2015, and the apparent population peak in 2013 is comprised almost entirely of very light defoliation levels. As forest tent caterpillar populations peak every 10-16 years in Minnesota, we may expect to see increasing levels of defoliation beginning in 2020 and the next population peak sometime between 2023 and 2029 (assuming that a true population peak occurred in 2013).

Congregating forest tent caterpillars.



Areas with forest tent caterpillar defoliation.



Gypsy moth

The Minnesota Department of Agriculture Division of Plant Protection (MDA) leads the Minnesota gypsy moth program *(*https://www.mda.state.mn.us/plants/pestmanagement/gmunit*)*. The following is an excerpt from a report on the 2019 survey year.

Survey and trapping

The MDA and cooperators have conducted surveys for gypsy moth since 1973. In 2019, MDA staff and cooperators placed 21,794 detection traps statewide, mostly along the eastern border of Minnesota. Statewide captures totaled 544 male moths.

Staff found immature gypsy moth life stages, including egg masses, at three sites, at which treatments are being proposed for 2020:

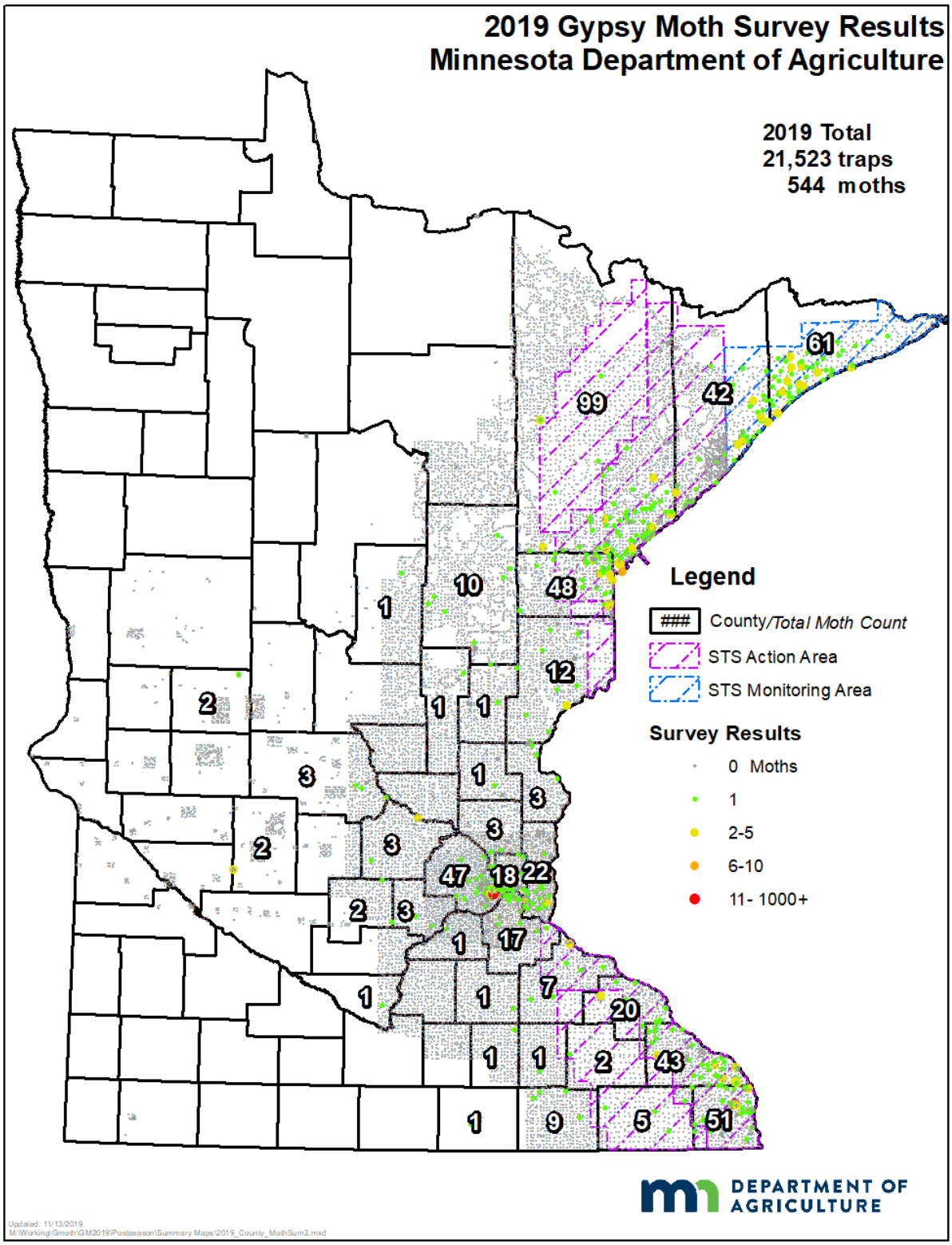
1. A rural site southwest of Oak Center (Wabasha Co.)
2. A rural site west of Hokah (Houston Co.)
3. A site just north of the Minneapolis-St. Paul International airport in urban SE Minneapolis (Hennepin Co.).

The MDA trapping survey will continue to place around 20,000 traps along the eastern edge of Minnesota, with special attention paid to high-risk sites such as nurseries, mills, parks, and urban communities. There will likely be a western rotation (focusing on select municipalities and high-risk sites) if funding is available.

Treatments

Aerial applications of *Bacillus thuringiensis kurstaki* were conducted at three sites in the spring of 2019: Chisholm (St. Louis Co.), 135 acres; Lakeville (Dakota Co.), 133 acres; and Stillwater (Washington Co.), 633 acres. Gypsy moth immature life stages were found at each of the treatment sites in 2018.

The three areas listed above where MDA found alternate life stages in the 2019 survey season are being proposed for 2020 treatment sites. The total acreage for the three sites will be around 2,500 treatment acres.


2019 Gypsy Moth Survey Results
Minnesota Department of Agriculture
2019 Total
21,523 traps
544 moths
Legend
County/Total Moth Count
STS Action Area
STS Monitoring Area
Survey Results
0 Moths
1
2-5
6-10
11- 1000+
99
42
61
10
48
1
12
1
1
2
3
1
3
3
3
2
47
18
22
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DEPARTMENT OF AGRICULTURE
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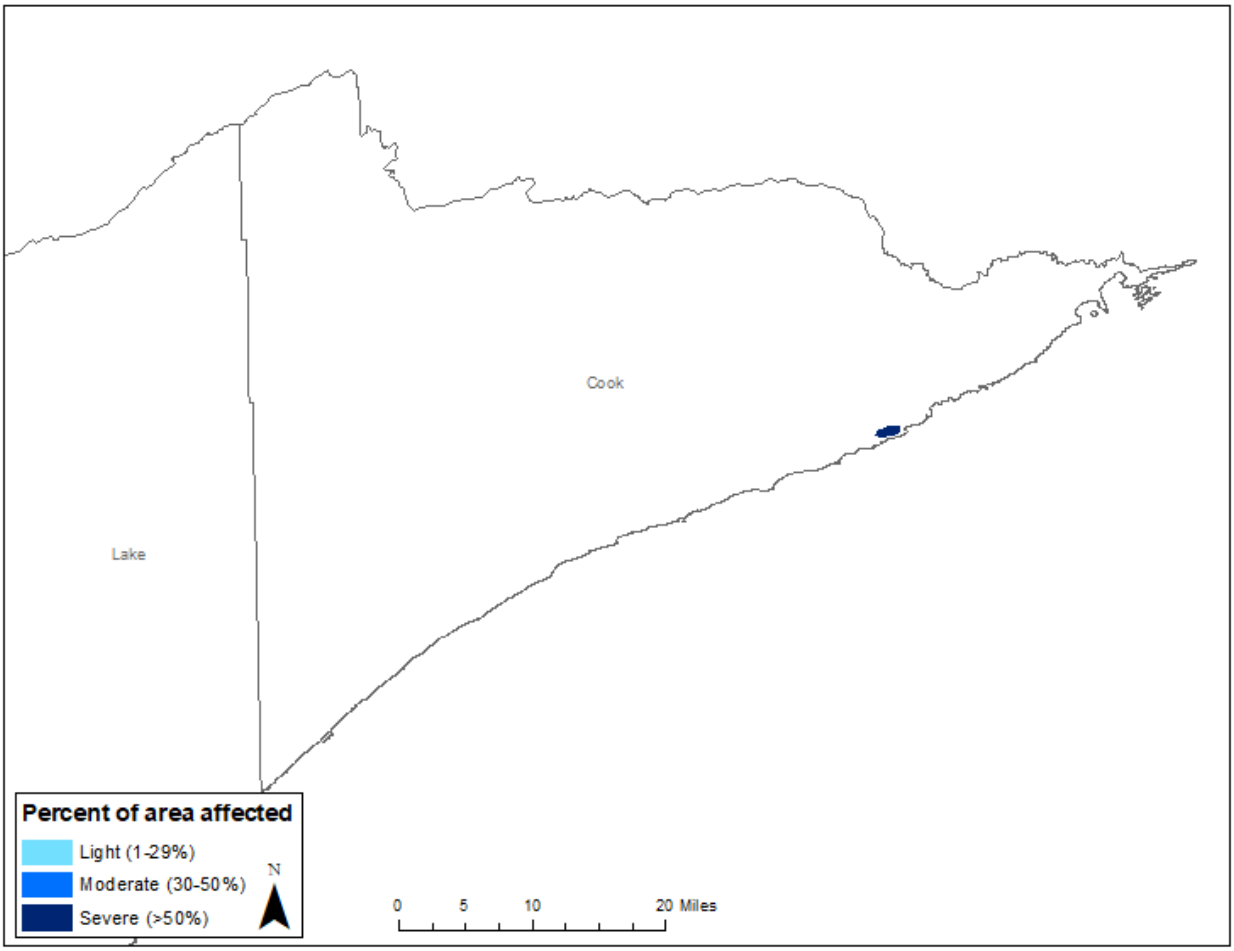
Jack pine budworm

Jack pine budworm is a native moth whose caterpillar feeds on jack pine. It defoliated over 70,000 acres each year in 2005 and 2006, but the population peak in 2015 affected less than 6,000 acres. This year only a small area in Cook County northeast of Grand Marais was severely defoliated by jack pine budworm. We mapped 609 acres of damage in this area, which was actually an increase in acres defoliated from last year. Jack pine budworm populations collapsed last year elsewhere in Minnesota, and those populations have not recovered. Jack pine populations peak every eight to 10 years in Minnesota, and we expect the next population peak to occur sometime between 2023 and 2025.

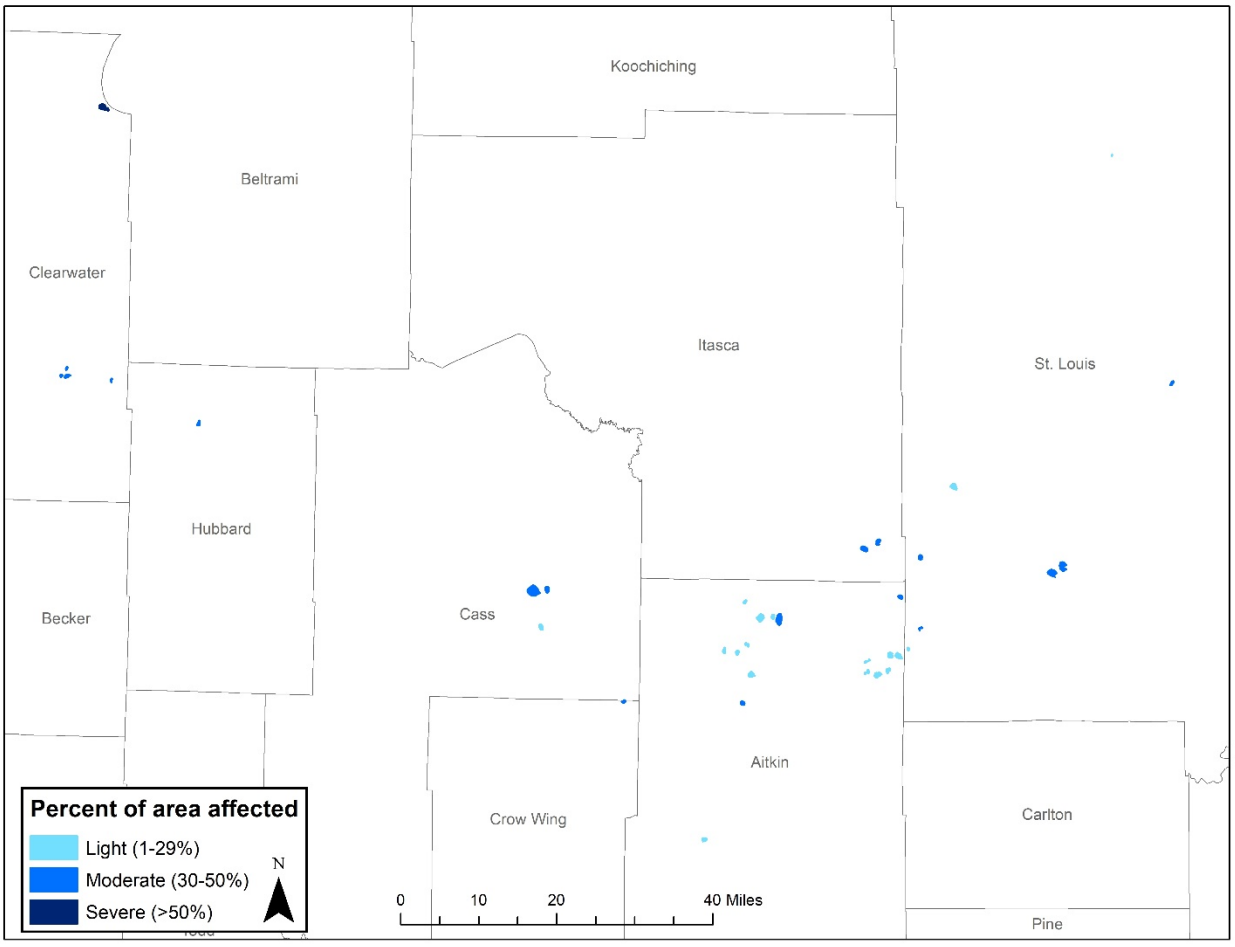


Jack pine budworm defoliation was mapped only in eastern Cook County along Lake Superior.

Larch casebearer

Larch casebearer is a non-native moth whose caterpillar feeds on tamarack needles and can cause defoliation when populations are high. Mortality from defoliation has not been recorded in the state, but it is a possibility.

We mapped 7,168 acres affected by larch casebearer in 2019. This is a decrease of about 55 percent from last year, which continues a downward trend first noticed in 2018. This doesn't mean the population will continue to decline in successive years, however.



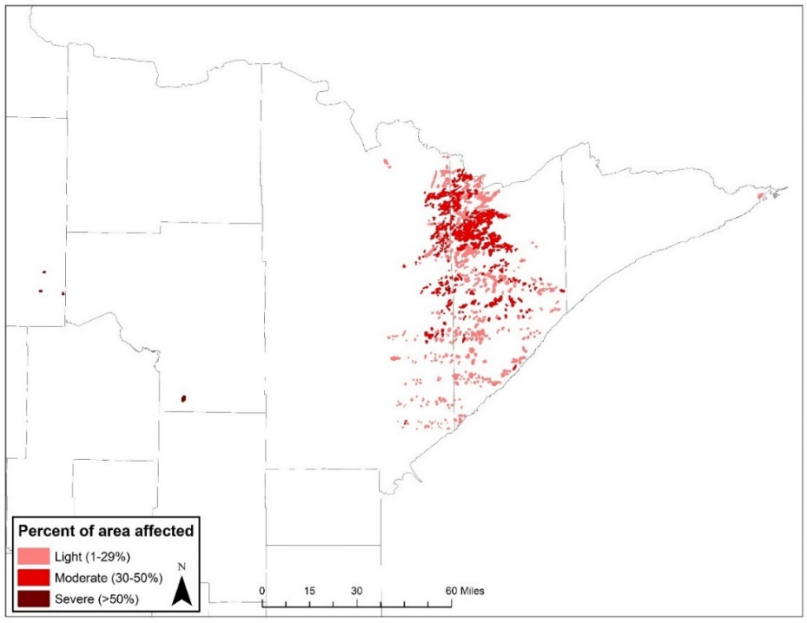
Larch casebearer defoliation found in Aitkin, Cass, Clearwater, Hubbard, Itasca, and St. Louis counties.

Spruce budworm

Spruce budworm is a native caterpillar that prefers to feed on balsam fir, but also readily feeds on white spruce. This needle-feeding caterpillar has been recorded defoliating many acres of forests in various areas in the Arrowhead Region every year since at least 1954. The earliest recorded damage in Minnesota dates back to 1912. This outbreak lasted until the early 1920s, which is more typical for an outbreak. However, since 1954 there has been a consistent population of spruce budworm in the Arrowhead Region. Currently, spruce budworm typically feeds in a given zone for about eight years, which is the maximum period of time in which balsam fir can sustain defoliation before it dies. The population will then move to a different zone in northeast Minnesota and start to feed.

We mapped 201,711 acres impacted by spruce budworm in 2019. This is very close to what was mapped in 2018 with 196,460 acres. Also similar to last year, the heaviest spruce budworm landscape-level impact was in an area southeast of Ely that is mostly Superior National Forest land. The outbreak in this area will most likely be active until 2021. Newly impacted areas are occurring in eastern Lake County and gradually into Cook County. Overall, the average amount of acres impacted by spruce budworm since 2000 has been about 100,000 acres.

The spruce budworm defoliation and mortality aerial survey data are being incorporated into Community Wildfire Protection Plans by St. Louis County, the DNR, and the USDA Forest Service. Since dead standing conifers with needles can increase the risk of quickly spreading wildfires, this is wise community planning to prevent extensive wildfires.



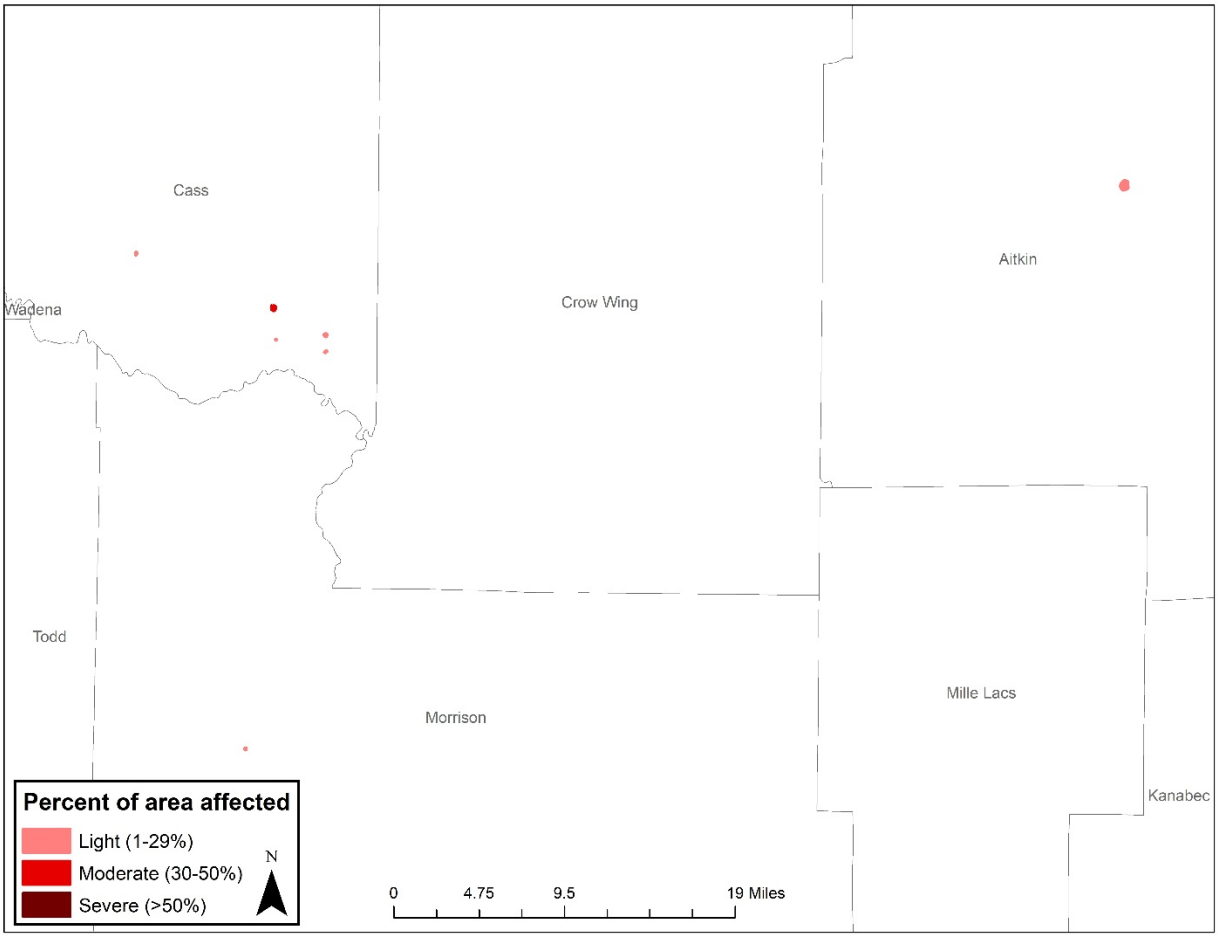
Spruce budworm defoliation and mortality In the Arrowhead Region of Minnesota.

Twolined chestnut borer

Twolined chestnut borer is a native inner-bark-feeding beetle that attacks stressed oak trees. It can cause widespread dieback and mortality of oaks after serious droughts, wind storms, or intense and repeated defoliation events.

Only 220 acres were impacted from twolined chestnut borer this year, about a 78 percent decrease from 2018. This was anticipated, as there was adequate precipitation this year to keep trees from being stressed.

Mortality from twolined chestnut borer can occur in a single year, but it usually takes two to three years. Symptoms can resemble those from oak wilt. A distinctive difference is that dead leaves will stay on oak trees suffering from twolined chestnut borer, but oak leaves will rapidly fall off an oak infected with oak wilt. This is especially true with red oak.

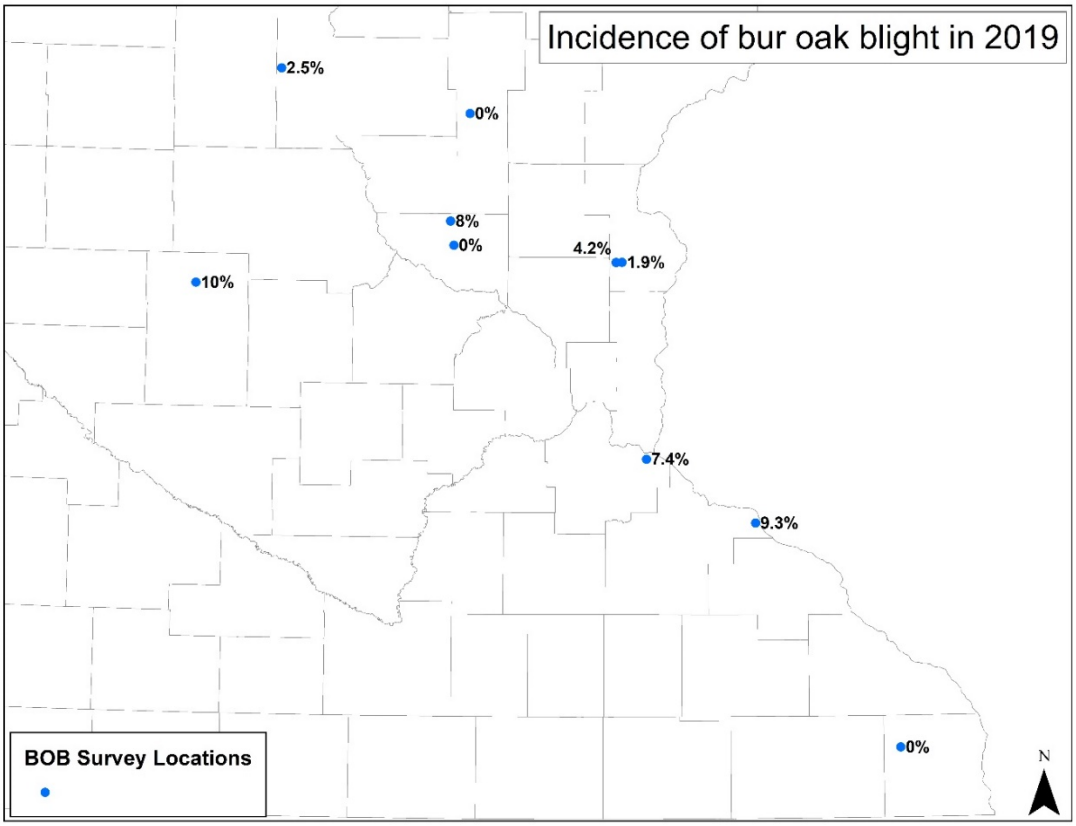


Twolined chestnut borer damage was seen in Aitkin, Cass Mille Lacs, and Morrison counties.

Bur oak blight

Bur oak blight is a native leaf disease of bur oak that causes leaves to brown (and *sometimes* drop) in late summer. Vigorous trees recover and look normal again the following spring. In our 2006 annual report, forest health staff noted an increase of bur oak blight in southern Minnesota. That upward trend in abundance has generally continued for the past 13 years, promoted by consecutive years of wetter-than-average springs.

Bur oak blight symptoms were substantially more abundant in 2019 than in 2018, likely due to below-normal May precipitation in 2018 and above-average May precipitation in 2019. Surveys of 480 bur oak trees across 10 sites showed that about four percent of bur oaks were substantially defoliated by bur oak blight by early October 2019 (see survey results in the map below). With an anticipated increase in precipitation in the coming springs due to a changing climate, we expect to continue to see the bur oak blight causal agent defoliate noticeable numbers of bur oaks by early autumn.



Bur oak blight (BOB) survey locations and results in the southern half of Minnesota.

Diplodia

Diplodia is a fungal pathogen that frequently kills red pine seedlings, causing crown loss and top-kill on mature pines after stressful conditions. Unfortunately, *Diplodia* can also cause latent infections, those that show no signs of disease until trees become stressed. In 2016, the Badoura State Forest Nursery destroyed 400,000–500,000 red pine seedlings with possible latent infections in order to avoid distributing unhealthy seedlings. Traditionally when latent *Diplodia* infections are above 10 percent we advise destroying the nursery crop.

To understand the fate of the seedlings had they been planted in the field, the forest health unit planted 616 bare-root seedlings from the affected Badoura seedling bed in a vacant field at the General Andrews Tree Improvement Center in Willow River, Minnesota in April 2017. To compare mortality of infected and uninfected stock, 628 uninfected containerized seedlings from an outside source were planted next to the bare-root seedlings from Badoura.

Planting project at the General Andrews Tree Improvement Center to assess the impact of latent Diplodia infection.

Forest health staff assessed mortality twice annually in 2018 and 2019. Ninety-five percent or more of seedling mortality happened within five-and-a-half months of planting in 2017, so the forest health team closed this project at the end of 2019. Sixty-two percent of the bare-root stock had died by October 2019, in contrast to 25 percent of the containerized stock. We estimate that at least 67 percent of the bare-root mortality was due to *Diplodia* collar rot, presumably resulting from latent infection. Our tentative conclusion is that the test for latent *Diplodia* infection may drastically underestimate latency. We plan to repeat this experiment in the near future and also test if surveys of *Diplodia* shoot blight in nursery beds might better predict mortality from *Diplodia* in the field than expensive latent testing.

Badoura State Forest Nursery has assessed levels of latent *Diplodia* infections annually since 2016. There was good news from their 2019 analysis: only 0.26 percent of tested stock had latent *Diplodia* infections, which is an acceptable level. This is the third consecutive year where latent *Diplodia* infections at the state nursery were at acceptable levels.

Heterobasidion root disease

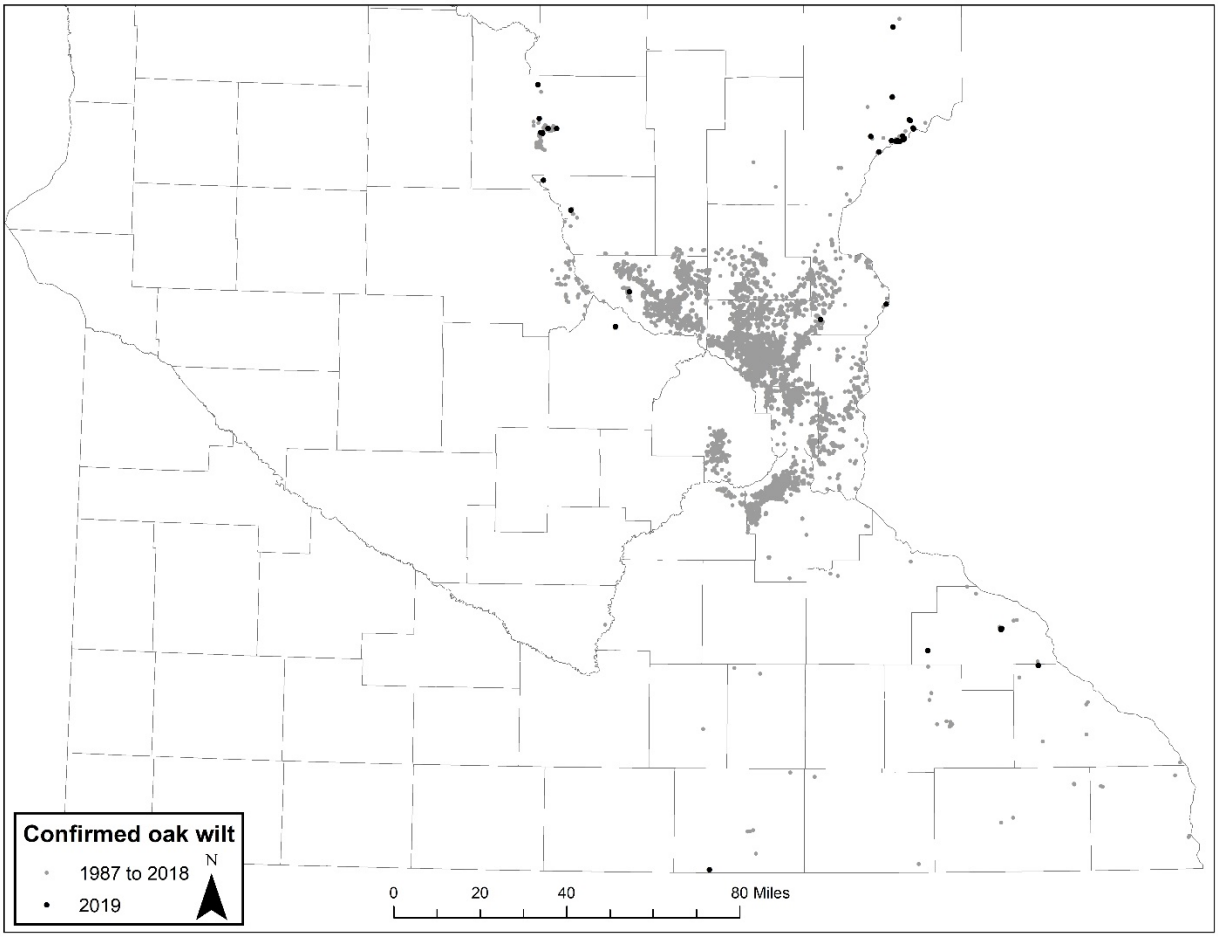
Heterobasidion root disease is a potentially serious and persistent fungal disease in pine plantations. University of Minnesota staff first confirmed it in Minnesota in 2014 in a state-managed red pine plantation in Winona County. We took steps to eradicate *Heterobasidion* from the site in 2017, and did not detect any *Heterobasidion* fruiting bodies on extracted stumps at the site in 2018 or in 2019. We will conduct visual surveys for *Heterobasidion* fruiting bodies or spore detection surveys at this site in 2020.

In addition to the Winona County site, we investigated dying mature red pine in at least one site in each of Cass, Cook, Lake of the Woods, Mille Lacs, St. Louis, and Sherburne counties. We found no *Heterobasidion* during any of these investigations.

Heterobasidion conk circled in red.

Oak wilt

Oak wilt is a non-native, fatal oak disease that has been spreading slowly northward in Minnesota since the 1940s. It can be devastating in nearly pure oak forests. The disease currently covers about 30 percent of the state's red oak range and is common in east-central and southeast Minnesota.



Points across central and southern Minnesota where oak wilt was confirmed from 1987 through 2019.

In order to slow oak wilt's northward spread into currently uninfected forests, we prioritized early disease detection, outreach efforts, and management at two strategic locations, the northern three-quarters of Pine County and all of Morrison County.

Early Detection

Aerial surveys and aerial photos helped with early detection of oak wilt in 2019, followed by confirmation from the ground. We identified 42 new oak wilt pockets in Morrison County and 18 new pockets in northern Pine County. The aerial survey in Morrison County identified oak wilt about eight miles farther north than previously known, an important finding.

A red oak wilting rapidly from oak wilt.

Management in Pine County

In Pine County, a federal grant has provided funding since 2017 for the DNR to control oak wilt in St. Croix State Park. From 2017 to 2019, state park staff controlled all known oak wilt pockets, averaging 19 per year. The DNR forest health team has applied for another oak wilt control grant for 2020, not only for St. Croix State Park, but for all public lands in northern Minnesota.

Besides managing oak wilt in the state park, the DNR Division of Forestry forest stewardship program provided recommendations and cost-share to control oak wilt on private parcels in Pine County. At the end of 2019, 10 out of 11 known oak wilt pockets on private lands had been controlled in the northern three-quarters of Pine County.

Management in Morrison County

The Morrison County Soil and Water Conservation District received funding from the Environment and Natural Resources Trust Fund for oak wilt control on private lands beginning in 2019. The underground spread of oak wilt was controlled on 25 pockets in late 2019 with the funds. A contractor plans to destroy the infected oaks from those pockets in early 2020. The DNR Division of Forestry played a key role in identifying oak wilt, advising private property owners, and determining control lines.

Besides oak wilt on private land in Morrison County, we also knew of two state-managed land parcels with oak wilt. The Little Falls DNR Forestry staff eradicated oak wilt on one of those parcels and was actively seeking a logger to eradicate oak wilt on the second state-administered parcel as of late December 2019.

Brown pockets of oak wilt near Little Falls.

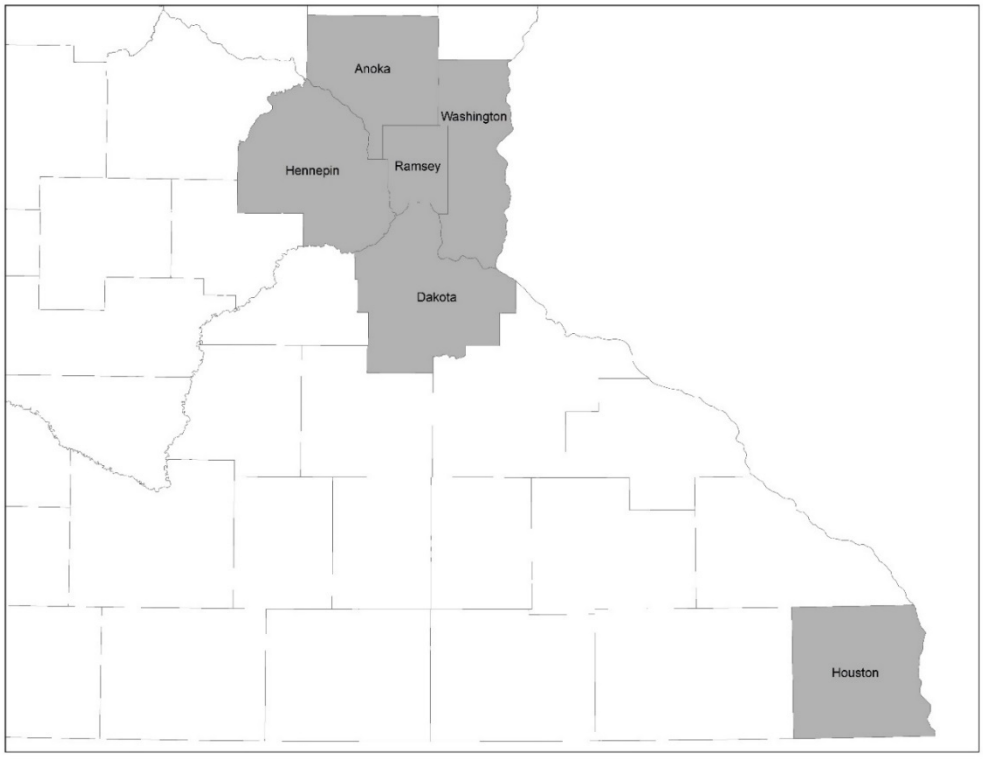
Altogether 33 percent of known oak wilt pockets were controlled in Morrison County in 2019, probably an underestimate due to undetected oak wilt infections. The Morrison County Soil and Water Conservation District plans to re-apply for oak wilt control funds for private lands after 2019, and the DNR forest health team plans to continue to prioritize oak wilt control in northern Morrison County.

Tubakia shoot blight on white oak

A blighted white oak shoot from *Tubakia*.

Resource managers noted severe shoot blight on widely scattered white oaks starting in late August, 2019. In many cases, more than 50 percent of the canopy appeared affected. Petioles turned black and the tips of new shoot growth became necrotic. Forest health staff sent samples to the University of Minnesota Plant Disease Clinic for analysis, where they isolated the fungus *Tubakia dryina* from symptomatic shoots. We suspect the abundance of precipitation from May through September enabled this pathogen to cause disease on the white oaks.

According to the Minnesota DNR's Climate Trends website, the southeast and east-central climate divisions in Minnesota received 6.4 inches more precipitation from May through September than the long-term (1895-1990) mean for that time-frame.

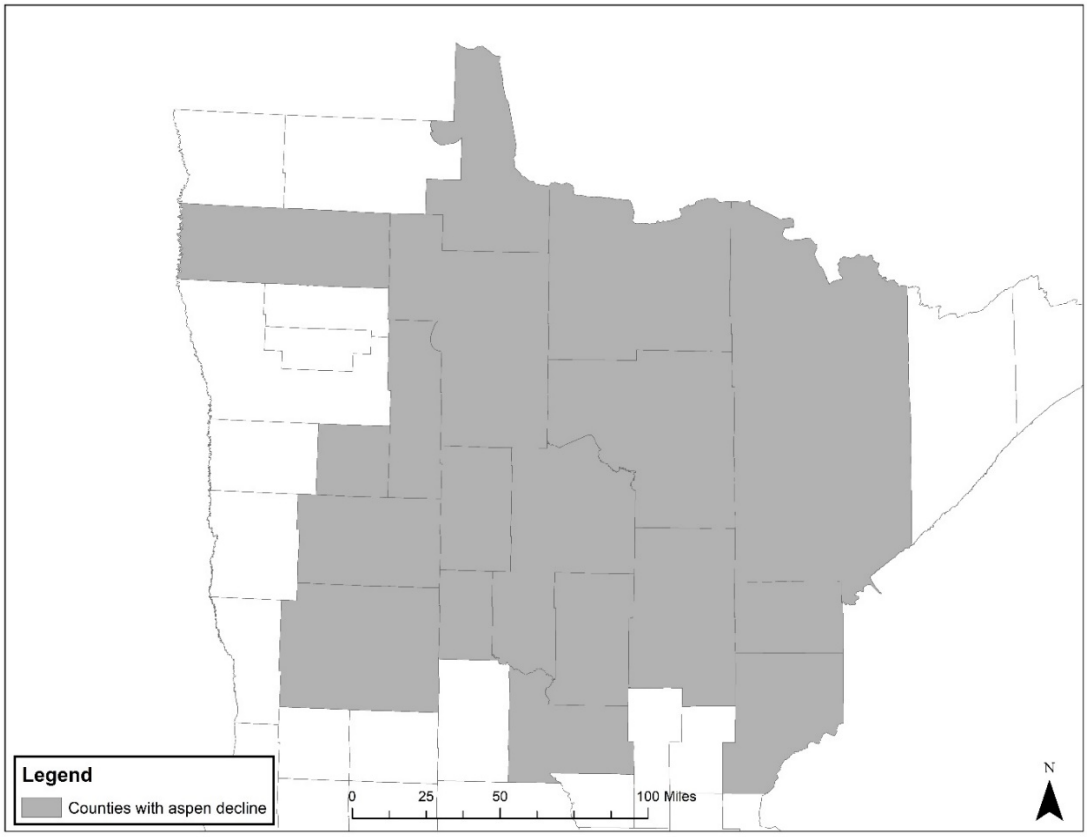


Counties with white oaks with severe dieback from Tubakia.

Aspen decline

We mapped 16,905 acres of aspen decline in 2019, a similar number to what was mapped from 2016 to 2018. The causes of aspen decline are varied and can't be contributed to one factor. Leaf discoloration and dieback are symptoms that can occur, and eventually mortality can result.

Aspen and birch decline have been documented in aerial surveys in Minnesota since 2004. Past aspen and birch decline were regionally isolated. Currently, they are located in relatively small declining areas scattered across northern Minnesota. The areas of decline are likely unique to the region or site. Probable causes of decline include a combination of old age, flooding, regional drought, wind, and other stresses. Particularly, much of northwest Minnesota experienced unusually dry weather from May through September in 2011-2013, 2015, 2017, and 2018, which could have resulted in more decline in the region.



Aspen decline can be found in nearly all of northern Minnesota.

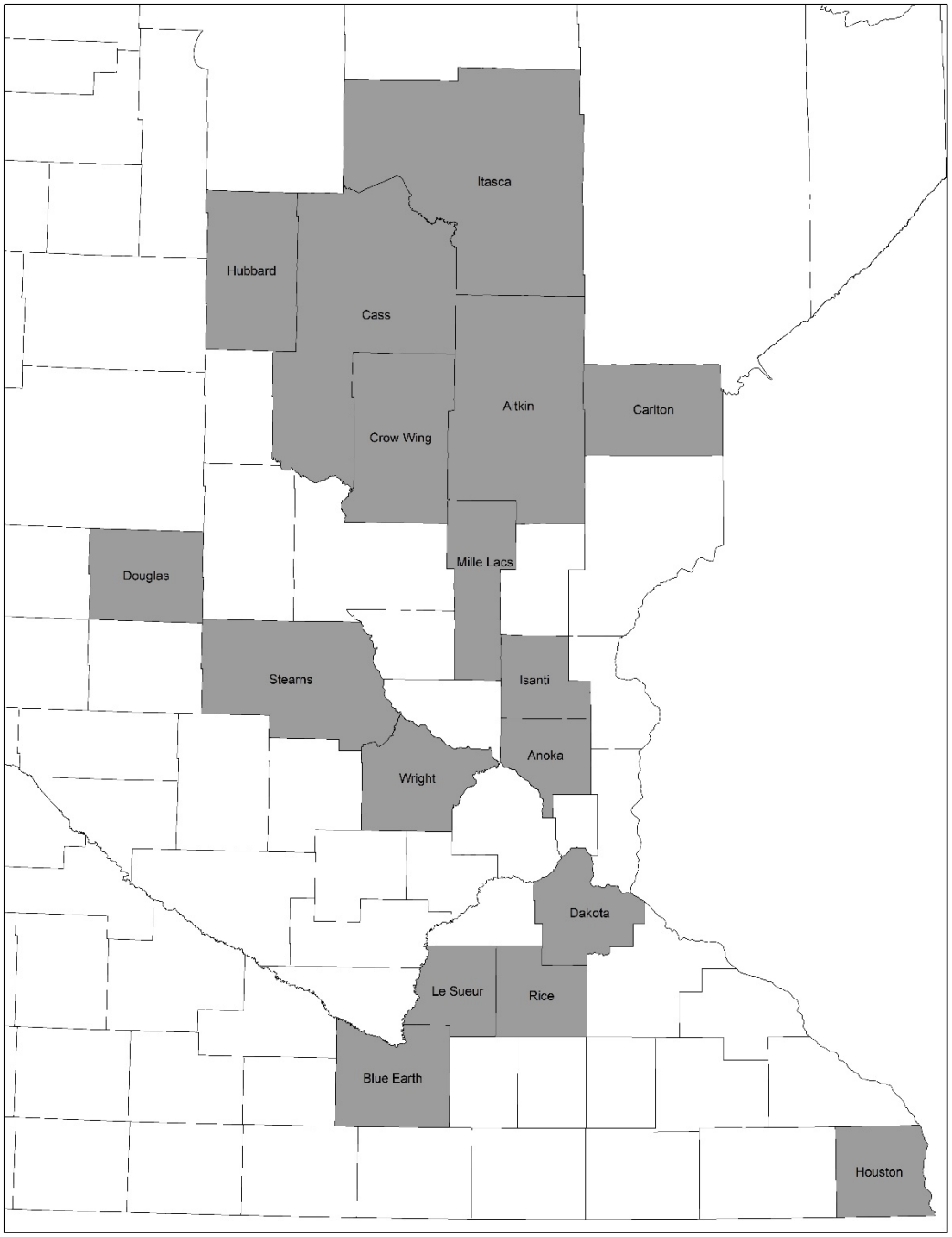
Urban and residential maple and ash dieback

Beginning in early June and ending in mid-August, community foresters and residents across a large swath of central and southeast Minnesota (map on following page) reported scattered maple and ash with severe and apparently sudden dieback. All dieback occurred on maple and ash growing in communities and in rural residential yards. We were unable to investigate these situations in the field in depth, but we estimate that the percentage of urban maple and ash with these symptoms was very small. The abundance and widespread nature of the reports, the timing of similar symptoms appearing on two unrelated trees, and symptoms appearing only on yard trees strongly imply an environmental cause.

A maple with sudden dieback. Photo by Tom Strack, Crow Wing County environmental services specialist.

Trees growing in urban environments and yards are more susceptible to environmental stress than trees growing in forests. The soils in which residential trees grow are often compacted; trees are impacted more by excessive precipitation and lawn irrigation. Some ornamental trees, even though they might be native to Minnesota, could be ornamental varieties sourced from an area south of Minnesota and not as cold-hardy as native trees grown in Minnesota. Weather events that occurred in the affected areas and could have impacted stressed yard maples and ash were (1) an unusually wet fall in 2018, (2) no snow cover for the majority of December 2018, (3) cold air temperatures in late January 2019 that had not occurred for 23 years, and (4) an unusually wet spring in 2019.

Some of the ash and a few of the maples actually died in 2019. Many of the maples had severe dieback, but if less than 50 percent of their canopy died, we predict they will survive into 2020.



Counties with dieback and mortality in maple and ash yard trees.

Older bur oaks dying in forests from multiple stressors

Over the last few years, the forest health team has investigated an increasing number of sites with bur oak dieback and mortality. Most sites have been in the southern half of Minnesota, but some investigations were in the north as well. In all cases, a noticeable percentage of bur oaks died over the last few years, usually scattered across the forest. Forest Inventory Analysis data show that the annual mortality rate of bur oaks larger than 12 inches in diameter has increased substantially over the last 14 years in south-central and southeast Minnesota.

The sites we investigated had scattered bur oaks dying slowly from the outer part of the crown downward. We think this scattered, slow death is a result of drought and excessive precipitation stressing old trees, which eventually are finished off by a couple of opportunistic pests. Those opportunistic pests, *Armillaria* and twolined chestnut borer, were often found on dying trees.

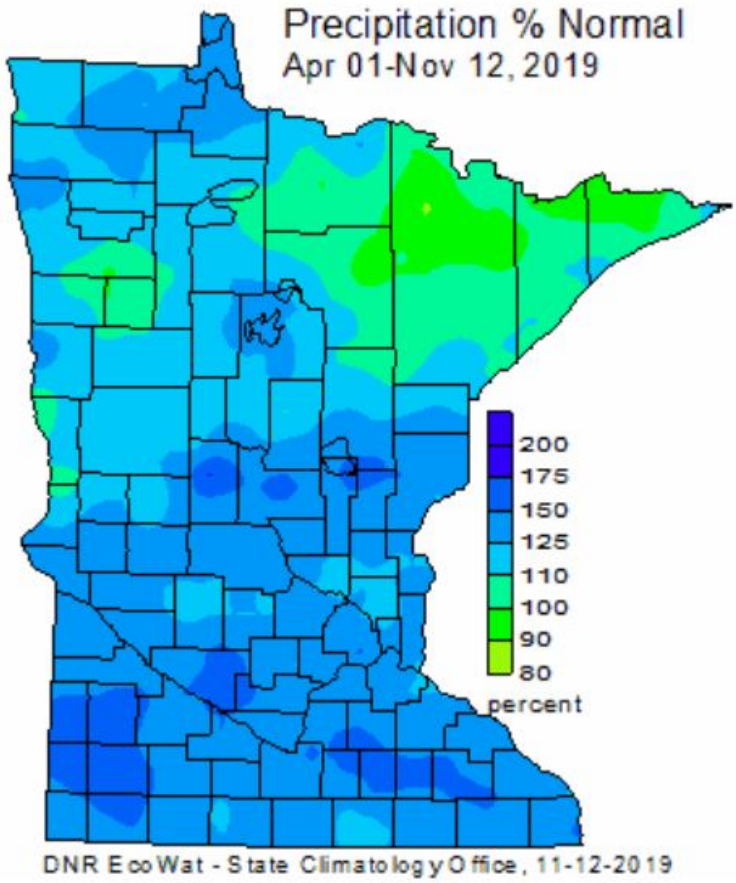
We have found no consistent primary tree killer such as oak wilt on these sites, and we do not believe bur oak blight or herbicide drift are fundamental parts of the problem. Besides old age possibly predisposing these oaks to stress, we've had several growing seasons during which precipitation was either too low or excessive. Drought occurred in various years in east-central, south-central, and southeast Minnesota from 2006 to 2013. Much higher-than-normal precipitation happened in the years afterward, which in some instances clearly helped kill oaks near wet areas.

Bur oaks dying from flooding and *Armillaria.*

Unfortunately, the decline of older trees likely cannot be reversed. In many cases, invasive plants are dominating areas in the forests where bur oaks are dying, a major concern for sustaining a healthy forest. We anticipate the number of declining bur oaks will increase as unmanaged woodlots age and are exposed to greater amounts of precipitation during the growing season. DNR forest health will continue monitor this phenomenon.

Flood damage

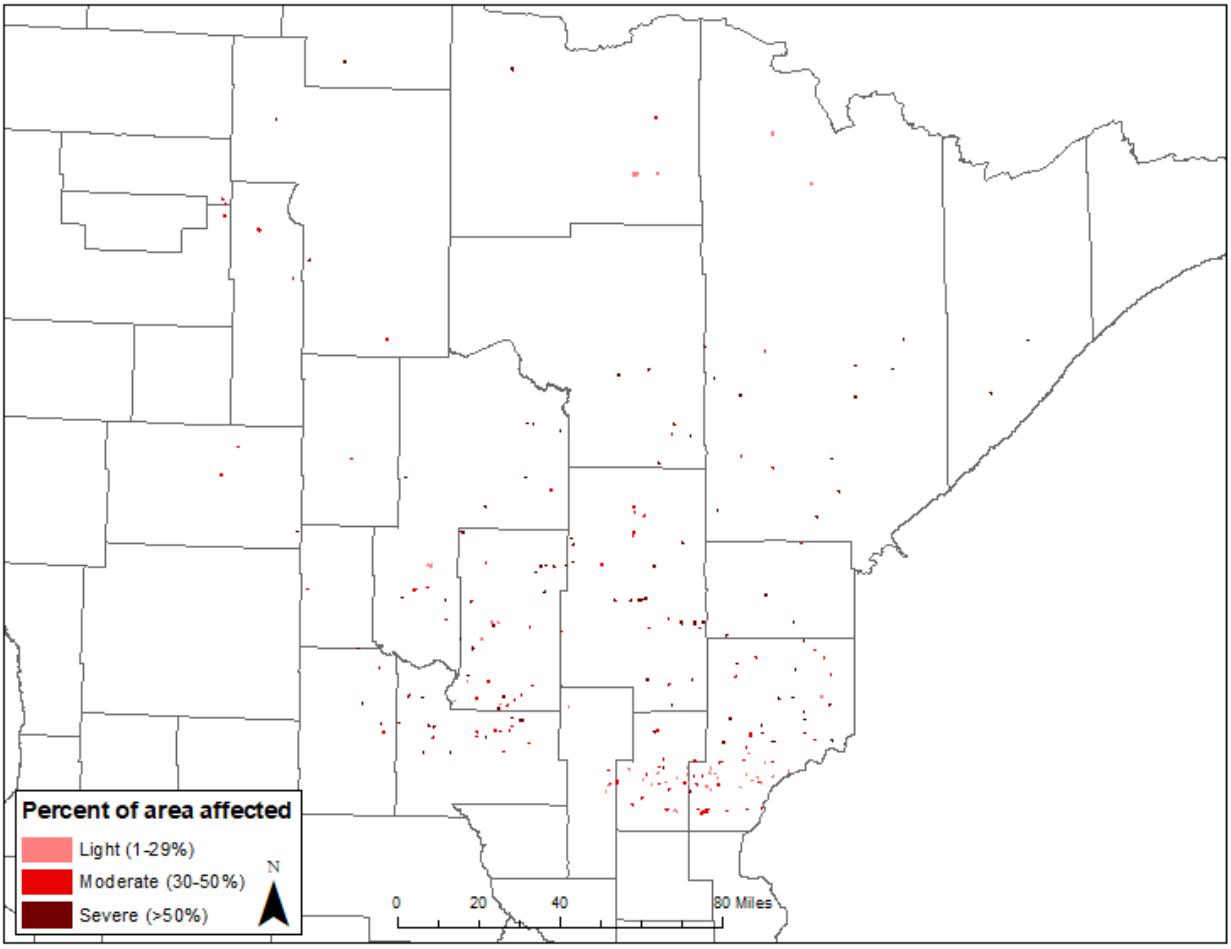
We mapped 9,073 acres of forest damaged by flooding across Minnesota, a nearly 80 percent increase from 2018. There were record-breaking levels of precipitation in areas of southern and south-central Minnesota we did not aerially survey this year, so our results underestimate the full extent of flood damage to forests. The US Geological Survey Waterwatch website (https://waterwatch.usgs.gov/?id=ww_current) reported that the following counties had streamgages (instruments that measure and record the amount of water flowing in a river or stream) indicating at least three weeks of flooding at moderate or major flood stages from March 8 through May 31, 2019: Brown, Carver, Chippewa, Marshall, Nicollet, Polk, Ramsey, Redwood, Renville, Scott, Winona, and Yellow Medicine. The streamgage in Oslo (Marshall and Polk counties) experienced another 24 days at moderate flood stage from August through October.



No areas in Minnesota experienced drought this year, but some parts of the state experienced abnormally dry conditions at various points for intervals of a month or more throughout the

summer. Areas in the northern quarter of the state were periodically dry from May to mid-September, and small, scattered portions of the southern quarter of Minnesota were also dry in August. However, as of mid-November 2019, no areas are considered abnormally dry or in drought.

We mapped mostly moderate to severe flood damage across northern Minnesota; however, flood damage was likely extensive across southern Minnesota this year but was not aerially surveyed.



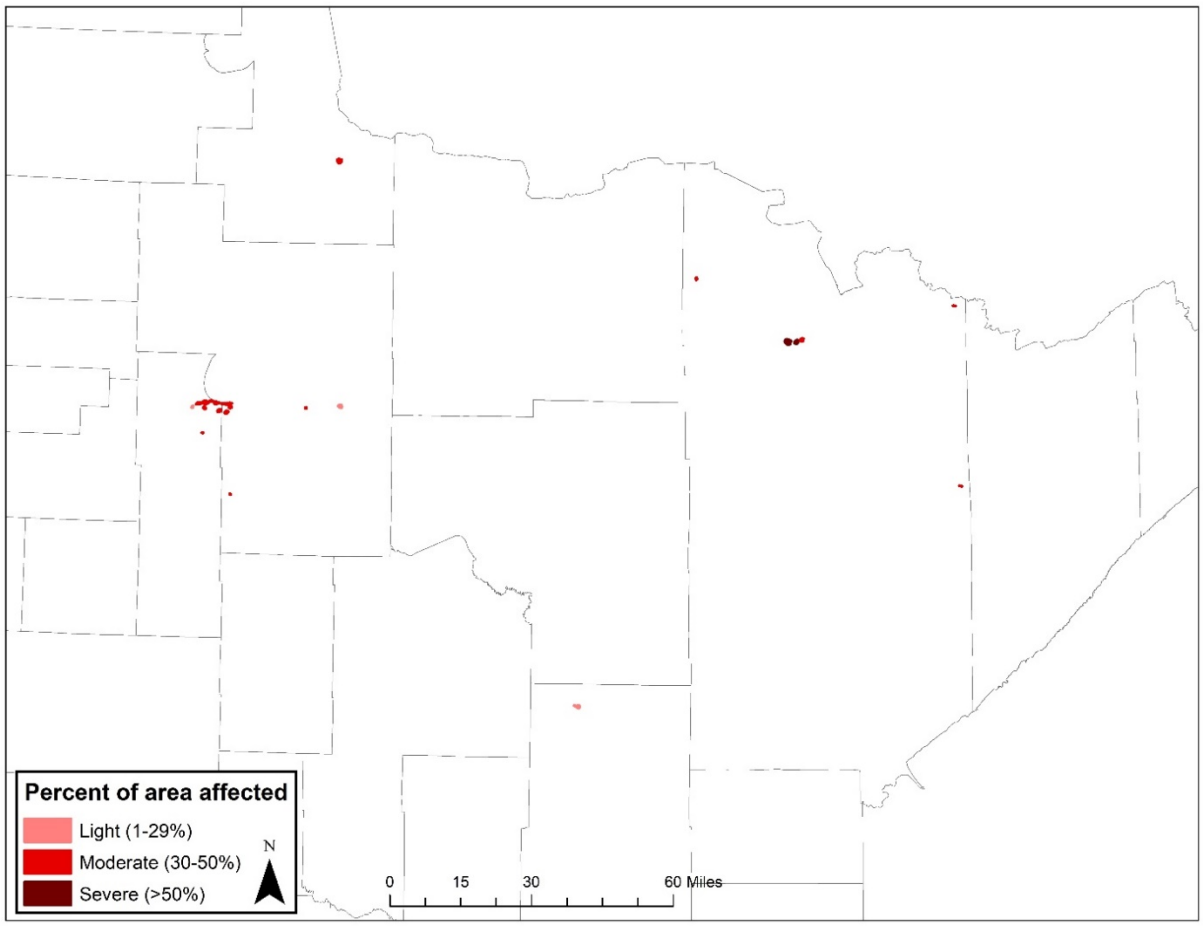
Mapped flooding damage in northeastern Minnesota.

Wildfire and prescribed burn damage

Only four fires in four counties were mapped during the 2019 aerial survey, located in Hubbard, Itasca, Roseau, and St. Louis counties. The fires damaged 275 acres of forest to some degree. Our assessment of fire damage is almost always an underestimate of fire damage to forests, since we survey during a short time span in the year, and we don't fly over all forests every year. Statewide, the DNR estimated 4,621 acres were burned in 634 wildfires. Many of these fires were on non-forested land.

Wind damage

Wind is a common forest disturber in Minnesota. We documented 5,225 acres of wind damage in 2019. There has been no clear trend in wind damage over the years. For example, the average annual amount of wind damage from 2003 to 2010 was 1,000 acres per year compared to an average annual amount of 9,800 acres from 2011 to 2019.



Moderate amounts of wind damage were recorded in Aitkin, Beltrami, Clearwater, Lake of the Woods, Pine, and St. Louis counties.

Other Tree Pest and Tree Health Events Noted in 2019

Pest or event	Pest stage or cause	2018 (county in which observed)	2019 (county in which observed)
Sudden death of conifers	Winter drying	Beginning May 10 (southern one-third of Minnesota)	Not observed
Dieback on bur oak	*Ceroptres* species (a cynipid wasp)	Beginning May 15 (Aitkin to Winona)	Not observed
Sudden ash leaflet drop	Anthracnose	May 27 (Itasca)	May 29 (Dakota) June 2 (Dodge) June 5 (Isanti)
Deformed leaves on oak	Anthracnose	Not observed	May 31 (Dakota) June 7 (Pine) June 10 (Kanabec)
Forest tent caterpillar	Caterpillars, 1-1.5 inches long	June 8 (Stearns)	Not recorded
Ips bark beetle	Egg-laying	Not observed	May 17 (Sherburne)
Larch casebearer	Larvae starting to feed	Not observed	May 28 (Chisago)
Oak wilt	Spore mats	Not observed	May 28 (Chisago)
Dieback on walnut	Winter cold temperatures	Not observed	June 11 (Houston) July 3 (Olmsted)
Oak wilt	Wilting noted for the first time in the year	June 19 (Anoka)	June 21 (Chisago)
Rust on glossy buckthorn leaves and fruit	*Puccinia* species	Not observed	June 21 (Chisago) July 9 (Isanti)
Dying boulevard lindens	Linden borer (*Saperda vestita*)	June 26 (Blue Earth)	Summer (Blue Earth)
Japanese beetle	Adults active	June 30 (Dakota)	July 1 (Ramsey)
Oak leaf skeletonization	Oak slug sawfly	Not observed	July 3 (Freeborn) July 9 (Isanti)

Pest or event	Pest stage or cause	2018 (county in which observed)	2019 (county in which observed)
Premature acorn drop	Bur oaks: unknown Red oaks: pip gall wasp	Not observed	July 12 (Hennepin) Summer (Blue Earth, Crow Wing, Nicollet, Pine)
Basswood leaf mining	Basswood leafminer (*Baliosus nervosa*)	Late growing season (northwest Itasca)	Late growing season (northwest Itasca)
Fall webworm nests	Caterpillars	Observed in various counties in southern Minnesota	Observed in various areas in southern Minnesota (more than last year)

Great Lakes Forest Fire Compact Forest Health Training

The Great Lakes Forest Fire Compact and Northeastern Forest Fire Protection Commission held a joint four-day oak wilt training workshop in Minnesota and Wisconsin attended by more than 30 forest health specialists and other forest health staff from the Midwest and northeastern US and Canadian provinces. Areas as yet unaffected by oak wilt or recently affected (New England and New York) are increasingly concerned about the potential impacts of oak wilt on their oak resources as it becomes detected in new areas. The purpose of the workshop was to provide insights into oak wilt management in a region where oak wilt has been an issue since the mid-1900s and to demonstrate that the effectiveness of oak wilt control strategies depends on many factors.

Participants attended a diagnostic workshop for oak wilt at the University of Minnesota and learned from the University's Plant Disease Clinic staff about look-alike issues and how to diagnose oak wilt cultures under a microscope, extract samples, and get the samples into culture. The training also included extensive field visits in both Minnesota and Wisconsin in collaboration with multiple federal, state, and local governments as well as tribal and University partners. Sites visited in Minnesota focused on symptoms in sand plain forests at the Carlos Avery Wildlife Management Area, research on double vibratory plow line methodology and effectiveness, oak wilt management at a large urban park operated by the Three Rivers Park District, and control of oak wilt in yard settings by Rainbow Tree Care Company. Locations visited in Wisconsin highlighted root rupture methodology, marking for treatment, and herbicide methodology at the Chequamegon-Nicolet National Forest as well as detection methodology, rapid response, and long-term effective oak wilt management conducted by Menominee Tribal Enterprises on the Menominee Indian Reservation. Demonstrations in both states included vibratory plow control, fungicide injections, and marking and felling trees during rapid response efforts.

University of Minnesota Plant Disease Clinic staff instruct workshop attendees. Photo by University of Minnesota.

Forest Pest First Detector Workshops

Forest Pest First Detector training continued in 2019 with one workshop held in St. Cloud. First Detectors are trained volunteers who respond to reports of exotic forest insects, diseases, and plants. Reports are initially made to "Arrest the Pest" at the Minnesota Department of Agriculture (MDA) by phone (888-545-6684) or email (Arrest.the.Pest@state.mn.us). The MDA contacts a First Detector near the location of the report and connects them to the reporting homeowner. The First Detector responds to help diagnose the problem and reports the finding to MDA.

Before attending the workshops, participants complete online training modules on various invasive pests. At the workshops, instructors are stationed at information tables, and participants rotate through the stations to learn identifying characteristics of the featured pests.

After the workshops this year, the 27 attendees were able to describe and identify signs and symptoms of emerald ash borer, Asian longhorned beetle, gypsy moth, spotted lanternfly, brown marmorated stink bug, oak wilt, jumping worms, Oriental bittersweet, burning bush, Japanese barberry, tree-of-heaven, burning bush, and European black alder. Attendees learned how to properly respond to reports of these pests.

The Forest Pest First Detector instruction team consists of agency partners who plan and create the agenda, decide on locations, organize registration, and present information on invasive insects, diseases, and plants at the workshops. The team includes staff from the University of Minnesota Extension, the Minnesota Department of Agriculture, and the Minnesota Department of Natural Resources. The workshops have been held annually since 2008.